Uncovering knowledge of core syntactic and semantic principles in individuals with Williams Syndrome

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Abstract

We present the results of an experiment designed to assess knowledge of core syntactic and semantic principles in individuals with Williams Syndrome (WS). The status of such knowledge is an important point of contention between competing accounts of linguistic abilities in this disordered population (e.g., Karmiloff-Smith, 1997, 1998; Karmiloff and Karmiloff-Smith, 2001; Clahsen and Almazan, 1998; Pinker, 1999; Tager-Flusberg, pleas-Skerer, Faja, and Joseph, 2003; Mervis and Becerra, 2007; Brock, 2007). Our experiment focuses on the logico-syntactic properties of expressions such as negation and disjunction (*or*) and tests knowledge of (a) core syntactic relations (scope and c-command), (b) core semantic relations (entailment relations and DeMorgan's laws of propositional logic), and (c) the relationship between (a) and (b). We begin by examining the performance of individuals with WS, children matched for mental age (MA), and typical adult native speakers of English. Here, performance on all conditions suggests that knowledge of (a-c) is present and engaged in all three groups. Results also indicate slightly depressed performance on (c) for the WS group, compared to MA, consistent with limitation in processing resources. This interpretation was supported by comparing individuals with WS to a group of younger, typically developing children. Results from this comparison show that the pattern observed in WS is the same as the one uncovered in younger, typically developing 4-year-olds. Overall, our results support the view that knowledge of grammar is not atypical in WS (Tager-Flusberg, pleas-Skerer, Faja, and Joseph, 2003; Brock, 2007; Thomas, in press). Broader implications of this conclusion for competing accounts of language development in WS, as well as for the relevance of WS to the study of cognitive architecture and development are discussed.

Key words: Williams Syndrome, syntax, semantics, modularity, neuroconstructivism, language, cognition, mental retardation.

1. Introduction

This article is concerned with the linguistic abilities of individuals with Williams Syndrome (WS). Over the past 20 years or so, WS has received considerable attention from scholars interested in the structure and development of the human mind. The main reason, as is well-known, is that this rare genetic disorder represents a natural experiment which suggests a potential dissociation between language and other aspects of cognition. To be sure, WS is often described as being characterized by relatively spared linguistic abilities in the face of serious deficits in other cognitive domains such as space and number (Bellugi et al., 1988; Bellugi et al. 1994; Bihrle et al., 1989; Karmiloff-Smith, 1992, 1997; Udwin et al., 1987; Mervis et al., 1999; Ansari, Donlan & Karmiloff-Smith, in press).

WS is thus often cited as evidence supporting the kind of modular view of mental architecture advocated most famously by Jerry Fodor (1983) and Noam Chomsky (1965, 1986, 1995) (Anderson, 1998; Bikerton, 1997; Piatelli-Palmarini, 2001; Pinker 1994). Recent developments, however, have led to a somewhat more nuanced picture of the linguistic profile of individuals with WS and, more importantly, to the emergence of two strongly conflicting views regarding the nature of linguistic abilities in this population.

On the one hand, proponents of modularity have argued that what is spared in WS is not language as a whole, as earlier accounts may have suggested, but rather, the computational system contained within the language faculty (i.e., the set of rules used to form words, phrases and sentences)[1] (e.g., Clahsen & Almazan, 1998; Pinker, 1999). On the other hand,

[1] Evidence for this comes from *within-domain* dissociations in WS language. Among the most widely cited evidence here is the idea that while syntax is relatively spared in WS, (lexical) semantics is somewhat aberrant (Bellugi et al. 1988; Rossen et al., 1996; Udwin et al., 1987; Temple et al., 2002). In the domain of morphology, some studies have found that people with WS perform better on regular forms than irregular forms, suggesting a dissociation between the computational machinery needed to generate tense and plural, and the lexicon itself (Bromberg et al., 1995; Clahsen et al., 2004; Pleh et al., 2003; Clahsen & Almazan, 1998; Zukowski, 2004; Penke & Krause, 2004). However, as Brock (2007) points out, studies in which larger groups of participants

recognition of such a potential *within-domain* dissociation, in conjunction with results from a small set of recent studies (e.g., Karmiloff-Smith et al., 1997; Volterra et al., 1996; as well as Capirci et al.,1996), have led some to the opposite conclusion, namely that grammar and morphosyntactic rules are in fact impaired or deviant in WS. These conclusions have been interpreted from the perspective of a new framework, called the 'neuroconstructivist approach', which represents an alternative to modularity (e.g., Karmiloff-Smith, 1998; Thomas and Karmiloff-Smith, 2002, 2005; Mareschal et al., 2007).

To further complicate the picture, recent accounts of WS, based on extensive reviews of the literature, interpret the facts about language abilities in this disordered population as neither compatible with modularity (broadly or narrowly construed) nor with neuroconstructivism (Brock, 2007; Thomas, in press). This conclusion stems from the observation that language abilities in WS neither exceed what one would expect on the basis of mental age – hence no dissociation between language and general cognitive abilities, contra modularity - nor reflect atypical or deviant underlying knowledge – as would be predicted by neuroconstructivism. This general observation is captured by what Karmiloff Smith and Thomas (2003) call the 'conservative hypothesis' (also see Brock, 2007 and Thomas, in press), according to which language development proceeds normally in WS but is delayed, due to the effects of mental retardation.

It is plain to see that these conflicting conclusions have significant implications for theories of the structure and development of the human mind (see Zukowski, 2001; and Brock, 2007 for detailed discussion). Thus, the incompatibility of some of the views described above regarding the nature and development of linguistic abilities in WS calls for a

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were used failed to uncover interactions between group (i.e., WS vs. controls) and regularity (Thomas et al., 2001; Zukowski, 2005).

broader investigation of grammar in this disordered population. A larger data set, in turn, will provide the kind of empirical wedge that one would need to begin teasing apart these competing accounts. Accordingly, we propose here to broaden the empirical basis upon which competing accounts of the linguistic abilities of individuals with WS can be evaluated.

In order to do so, we focus on the logico-syntactic properties of expressions such as negation and disjunction (i.e., *or*) and test knowledge of (a) core syntactic relations (scope and c-command), (b) core semantic relations (entailment relations and DeMorgan's laws of propositional logic), and (c) the relationship between (a) and (b). We selected these phenomena because they involve knowledge of core properties of the computational system of language and thus directly bear on the predictions of the two views under investigation.

Our principal question is whether individuals with WS interpret sentences in ways that require that they engage the core properties of the computational system described above. The crux of the issue here is whether language in WS is "spared" in the sense that individuals with WS know these core properties of language.[2] If not, does any impairment reflect abnormalities in the core linguistic sub-systems and structures within each? The relevant data are the absolute level of performance of people with WS, with the assumption that one simply cannot interpret the key sentences appropriately without engaging these properties.

A secondary question is how the performance of individuals with WS compares to neurologically normal individuals, including adult native speakers of English (who will provide a measure of ceiling), children matched to the WS group for mental age, and

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[2] The term "sparing" has been used in a variety of ways and has, in our opinion, caused confusion in the literature. For example, one sense of sparing -- an overly strong one -- predicts that people with WS will produce and comprehend language at the same levels as chronological age matched individuals. This is setting the bar far too high, we believe, since people with WS are typically moderately mentally retarded. In our paper, we use the term "sparing" to mean that people with WS will produce and/or comprehend language in a way that must engage knowledge of the rules and representations thought (in current theory) to underlie the aspect of language under test. Thus we rely strongly on theories of syntax and semantics to lay out the required rules and representations; and then we test to see whether people with WS perform in language tasks in a way that would require engaging these rules and representations. We discuss the criteria for this in section 5.1

children who are younger than mental age matches. To the extent that differences in absolute levels of performance emerge between individuals with WS and neurologically normal individuals, we can then ask whether performance *relative to other control groups* reflects different representations, or, alternatively, limitations in the processes that are used to carry out the computations required to understand and produce the relevant sentences.

To preview, our results demonstrate that knowledge of (a-c) is present in and engaged by individuals with WS, as it is by adults and typically developing children. We conclude that far from being 'superficial' - to use Karmiloff and karmilof-Smith's (2001) description – grammatical knowledge in WS is governed by the same abstract principles that characterize typically developing and mature systems.

2. Williams Syndrome: basic facts, theoretical perspectives and implications

Williams Syndrome is a rare genetic disorder with a prevalence of about 1/7,500 live births (Strømme et al., 2002) which is due to a micro-deletion of genetic material on chromosome 7 (Ewart et al., 1993). Individuals with WS present with both physical and cognitive abnormalities. Physical abnormalities include cardiac anomalies and unusual facial features, and cognition is characterized by an uneven profile with areas of relative strength, such as language, alongside severe weaknesses in domains such as space, number, planning and problem solving (Bellugi et al., 1988; Karmiloff-Smith et al., 1997 among many others). Even in the area of spatial representation and number, however, there are distinct strengths and a considerable degree of spared structure (Landau & Hoffman, 2007). The results on spatial representation in individuals with WS provides an important perspective: Although there are clear deficits in performance level, relative even to mental age matched children, many core aspects of spatial representation are preserved, suggesting that careful study might reveal the same for language. As mentioned earlier, competing perspectives have emerged regarding the linguistic abilities of individuals with WS. These different views can be seen as falling on a spectrum with the two main theoretical contenders, modularity and neuroconstructivism, on either end, and the more recent 'conservative hypothesis' somewhat in the middle. In the discussion below, we consider the main features of each of these perspectives.

2.1. The modular approach

As is well-known, the classic Chomskyan/Fodorian view maintains that the mind contains a domain-specific set of principles dedicated to the acquisition of language – a language 'module' or language 'organ' to use famous metaphors. In his seminal discussion of modularity, Fodor (1983) proposed that mental modules meet nine criteria, namely domain specificity, obligatory firing, inaccessibility to consciousness, speed, encapsulation, shallow outputs, localization, ontogenetic invariance, and characteristic breakdown patterns. It is important to point out, however, that Fodor did not intend for these criteria to be necessary properties of modules. Rather, to quote Fodor himself "One would thus expect – what anyhow seems desirable – that the notion of modularity ought to admit of degrees … When I speak of a cognitive system as modular, I shall therefore always mean "to some interesting extent." (p.37). Thus, it has been argued that Fodor's treatment of modularity suggests that he took it as a natural property, rather than something to be diagnosed through a checklist (see Sperber, 1994 for a discussion of this idea).

Moving beyond Fodor, subsequent theorizing has led many evolutionary psychologists to view modularity through the lens of functional specialization, a concept borrowed from biology (Pinker, 1997, 2005; Sperber, 1994, 2005; Tooby & Cosmides, 1992). To be sure, it has long been known to biologists that structure often reflects function. To use one of Pinker's (1997) analogies "It would be silly to try to understand why chairs have a stable horizontal surface by cutting them open and putting bits of them under a microscope. The explanation is that someone designed the chair to hold up a human behind." (p.314). Pinker (1997) goes on to tells us that he " … think[s] of the ways of knowing in anatomical terms, as mental systems, organs, and tissues, like the immune system, blood, or skin. They accomplish *specialized functions*, thanks to their *specialized structures* …[our emphasis]" (p.315). Thus, according to Pinker (1997), modules ought to be defined in terms of the operations they perform on the information that is relevant to them, rather than through an invariant set of necessary features (for a detailed discussion of these ideas and their implications for the notion of modularity, see Barrett & Kurzban, 2006).

Another important notion, held by most theoretical linguists, is that the language module itself has a modular structure and that it minimally contains two sub-modules, namely a lexicon - a list of stored entries specifying category membership for abstract entities such as nouns, verbs and prepositions, along with other idiosyncratic information - and a computational system – a set of rule-like operations which combine lexical entries to construct larger structures such as words, phrases and sentences (Chomsky, 1995). Given this view of language, proponents of modularity have argued that WS has a differential impact on the lexicon and computational system by affecting the former while sparing the latter (Clahsen and Almazan, 1998; Clahsen and Temple, 2003; Pinker, 1999). To quote Clahsen and Temple (2003): "They [Clahsen and Almazan, 1998] argued that these two core modules of language are dissociated in WS such that the computational (rule-based) system for language is selectively spared, while lexical representations and/or their access procedures are impaired." (p. 2)

2.2. The neuroconstructivist approach

Within the past decade, an alternative to the modular view has emerged, mainly under the impetus of work by Elman, Bates, Johnson, Karmiloff-Smith, Parisi and Plunkett (2001). These new ideas have been applied to neurodevelopmental abnormalities under a framework known as neuroconstructivism (Karmiloff, 1998; Karmiloff-Smith and colleagues (Karmiloff-Smith, 1997, 1998; Karmiloff and Karmiloff-Smith, 2001; Thomas and Karmiloff-Smith, 2005; Westermann et al., 2007; Thomas, in press). One of the paradigm cases for this approach is WS. At the heart of the neuroconstructivist view lie two important, related claims, namely: (a) that individuals with WS learn language using cognitive mechanisms that are different from the ones used by typically developing children, and (b) that *knowledge* of grammar and morphosyntax is compromised in WS[3].

The following quotes illustrate these two claims: "In sum … Williams Syndrome also displays an abnormal cognitive phenotype in which, even where behavioral scores are equivalent to those of normal controls, the cognitive processes by which such proficiency is achieved are different (Karmiloff-Smith, 1998:395), "The results of the two present studies … challenge the often cited claim that the particular interest of Williams Syndrome for cognitive science lies in the fact that morphosyntactic *rules* are intact [our emphasis] (Karmiloff-Smith et al. 1997:257), and finally "The final semantic and conceptual *representations* [our emphasis] formed in individuals with WS appear to be shallower, with less abstract information and more perceptually based detail …" (Thomas and Karmiloff-Smith, 2003:652).

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[3] In fact, the neuroconstructivist approach makes the following, additional claims (Karmiloff-Smith, 1998, p. 389) "(i) it seeks more indirect, lower-level causes of abnormality than impaired cognitive modules; (ii) modules are thought to emerge from a developmental process of modularization; (iii) unlike empiricism, neuroconstructivism accepts some form of innately specified starting points, but unlike nativism, these are considered to be innately 'domain-relevant', only becoming domain-specific with the process of development and specific environmental interactions; and (iv) different cognitive disorders are considered to lie on a continuum rather than be truly specific.

Thus, neuroconstructivism explicitly rejects modularity (specifically, the notion that the computational system of language is intact), on both empirical and theoretical grounds. To quote Karmiloff-Smith (1998) "This change in perspective means that atypical development should not be considered in terms of a catalogue of impaired and intact functions, in which non-affected modules are considered to develop normally, independently of the others. Such claims are based on the static, adult neuropsychological model which is inappropriate for understanding the dynamics of developmental disorders." (p. 390).

Another related claim is that language abilities in WS appear to be impressive, at least on the surface, because individuals with WS have good auditory memory skills. To quote Karmiloff and Karmiloff-Smith (2001) "It has become increasingly clear, therefore, that the superficially impressive language skills of individuals with WS may be due to good auditory memory rather than an intact grammar module" (p.202-3). Moreover, this approach emphasizes the role of rote learning in WS along with the relative inability of this population to extract underlying regularities and form linguistic generalizations. The following two quotes, from Karmiloff-Smith et al. (1997) illustrate these points "This suggests that if WS children go about language acquisition differently from normal children … they will end up – as they indeed do – with large vocabularies but relatively poor system building" (p. 257) and "We challenge these claims [about modularity] and hypothesize that the mechanisms by which people with WS learn language do not follow the normal path. We argue that the language of WS people, although good given their level of mental retardation, will not turn out to be "intact". (p.247)

Finally, some of the empirical evidence offered in support of the neuroconstructivist view comes from a study by Karmiloff-Smith et al. (1997) reporting that English-Speaking individuals with WS experience difficulty with the interpretation of embedded clauses and that French-speaking individuals with WS have trouble with certain aspects of grammatical gender. Unusual syntactic and morphological errors have also been reported by Volterra et al. (1996) as well as Capirci et al. (1996) who studied Italian-Speaking individuals with WS.

2.3. The conservative hypothesis

In more recent work, Thomas and Karmiloff-Smith (2003) consider, based on a review of the literature, two types of hypothesis regarding potential sources of atypicality in WS language. The first is what they call the conservative hypothesis "in which it is argued that the language we see in WS is merely the product of delayed development combined with low IQ" (p. 652). As an alternative to the conservative hypothesis, these authors propose the semantics-phonology imbalance theory which claims that language development in WS takes place under altered constraints. The specific idea here is that individuals with WS have a particular strength in auditory short-term memory accompanied by a relative weakness in lexical semantics. A major consequence of this imbalance is that individuals with WS rely more on phonological information than semantic information when processing language, which may lead to certain behavioral impairments.

In his review of language abilities in WS, Brock (2007) observes that there is in fact little evidence that the 'end state' of language development is atypical in WS, and, therefore, that there is no empirical support for Thomas and Karmiloff-Smith's semantics-phonology imbalance hypothesis. Instead, Brock concludes that by and large, the available evidence is consistent with the 'conservative hypothesis'. This conclusion is echoed by Thomas (in press) who acknowledges, citing Brock's (2007) study, that as research on WS progressed, the 'conservative hypothesis' has gained more support over the 'imbalance hypothesis'. Thus, Thomas' explicit goal is to find a compromise between modularity and neuroconstructivism. Finally, it is worth pointing out that Tager-Flusberg, Plesa-Skwerer, Faja, and Joseph (2003) arrive at essentially the same conclusion, as illustrated by the following quote from these authors: "Despite claims to the contrary (Karmiloff-Smith et al., 2002), there is no evidence that children with WMS acquire language any differently than other children, although they may be delayed in the onset of first words and phrases, as would be expected given their mental retardation (Morris & Mervis, 1999)" (p.20).

3. Theoretical and developmental Background

This section lays out the theoretical concepts and vocabulary that we will later be using to test WS people's knowledge of grammar. Studying the development of grammar – in typical or atypical populations – requires some familiarity with the framework used to study grammar in the first place, linguistic theory. Here we use sentences containing negation and disjunction (*or*) to uncover knowledge of much more abstract syntactic and semantic principles. Thus, our first task is to show what these abstract principles are and how they enter into explanation of the facts under investigation. Specifically, we introduce the syntactic notions of scope and c-command and the semantic notions of entailment relations and DeMorgan's laws of propositional logic. We also explain how these two sets of principles relate to each other. In a nutshell, we show that negation can interact with disjunction, *or*, to give rise to a pattern of entailment relations known as DeMorgan's laws of propositional logic. Whether or not the interpretation of negation and disjunction is subject to DeMorgan's laws, in turn, depends on the kind of syntactic relation holding between these two elements. Specifically, for DeMorgan's law to hold, *or* must occur in the scope (i.e., c-command domain) of negation. We then show that these principles, in addition to explaining what mature speakers know about English, have also been used to explain what younger, typically developing children know about their growing language.

Consider the sentences in (1-2).

(1) All of my students passed their exam.

(2) Some of my students passed their exam.

Notice that whenever (1) is true, (2) is also necessarily true. In other words, if it is the case that all of my students passed their exam, then it follows that some of my students passed their exam. Consequently, we say that (1) entails (2), but not vice versa (the fact that some of my students passed their exam does not necessarily mean that all of them did). More generally, we can say that propositions containing *all* entail equivalent propositions containing *some*, but not vice-versa, as shown in (3).

(3) All A are B ⇒ Some A are B

Next, consider the examples in (4-5).

(4) a. John bought a car.
b. John bought a red car.

(5) a. John didn't buy a car.
b. John didn't buy a red car.

Notice that (4a) does not entail (4b). In other words, if John bought a car, he didn't necessarily buy a red one. Interestingly, however, when the sentences in (4) are negated, as in (5), (5a) now entails (5b). Indeed, if it is true that John didn't buy a car, then it must also be true that he didn't buy a red car. Notice further that the kind of entailment relations created by the presence of negation have a directionality. That is, negation licenses inferences from sets (the sets of cars) to subsets (the set of red cars). Thus, negation is called a downward entailing expression, i.e. one that licenses inferences from sets to subsets. In contrast, the verb phrase (VP) of a declarative sentence creates an upward entailing context, namely a context in which inferences from subsets to sets are licensed. To be sure, (4b) entails (4a), but not vice versa: if it is true that John bought a red car, it is obviously also true that John bought a car. Here we have an inference from the set of red cars (the subset) to the sets of cars (the superset).

Scholars interested in natural language semantics have noticed that downward entailing expressions, such as negation, display an interesting set of properties. One such property concerns the interpretation of the disjunction operator, *or*. First, notice that in a declarative sentence such as (6), *or* typically receives a *disjunctive* interpretation. That is, the most natural interpretation of (6) is that John bought one kind of car or the other, *but not both*[4]. Another way to say this is that (6) does not entail (7). In other words, if John only bought a BMW, (6) would be true, but (7) wouldn't.

(6) John bought a BMW or a Mercedes.

(7) John bought a BMW and John bought a Mercedes.

Consider now what happens when (6) is turned into a negative, as in (8).

(8) John didn't buy a BMW or a Mercedes.

(9) John didn't buy a BMW and John didn't buy a Mercedes.

In the presence of negation, *or* is now interpreted *conjunctively*. That is, (8) is interpreted as meaning that John bought *neither* a BMW *nor* a Mercedes. Unlike in the case of (6) and (7), (8) now entails (9). This interpretive pattern, relating statements containing disjunction to statements containing conjunction is captured by one of De Morgan's famous laws of propositional logic, as shown in (10). Following standard logical notation, ¬ is the symbol

[4] We should point out that if John bought a BMW and a Mercedes, it is of course true that he bought a BMW or a Mercedes. In other words, statements containing *or* are pragmatically incompatible with equivalent statements containing *and*, but they are semantically compatible with such statements due to the entailment relation holding between conjunction and disjunction.

for negation, $\vee$ the one for the disjunctive operator, *or* , and $\wedge$ the one for the conjunctive operator, *and*. In plain English, (10) states that the negation of the disjunction of two propositions is logically equivalent to the conjunction of their negations.

(10) $\neg (P \vee Q) \Leftrightarrow (\neg P) \wedge (\neg Q)$

In light of the previous discussion, the examples in (11) and (12) would at first sight appear to be problematic. To be sure, both examples contain negation and the disjunctive operator, *or*, and yet, only (12) seems to obey De Morgan's law. In other words, (12a) entails (12b), but (11a) does not entail (11b). Put another way, we get a disjunctive reading of *or* in (11a) and a conjunctive reading in (12a). Why should this be?

(11) a. The man who didn't get a pay raise bought a BMW or a Mercedes.

b. The man who didn't get a pay raise bought a BMW AND the man who didn't get a pay raise bought a Mercedes.

(12) a. The man who got a pay raise didn't buy a BMW or a Mercedes.

b. The man who got a pay raise didn't buy a BMW AND the man who got a pay raise didn't buy a Mercedes.

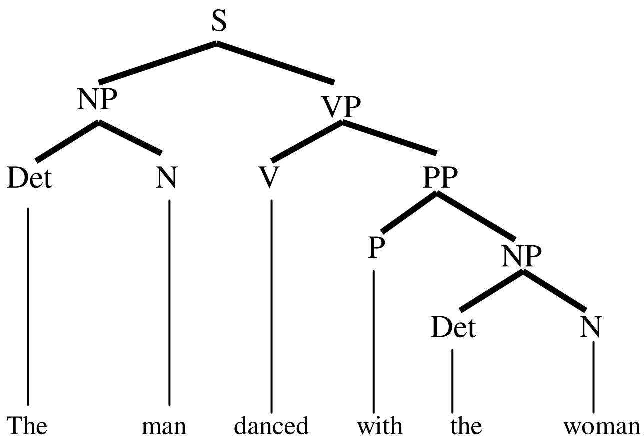
The short answer is that negation's powers are only potent in certain syntactic configurations. The detailed answer requires the introduction of three important and independently motivated theoretical notions: the notion of syntactic structure, the notion of scope, and the notion of c-command.

One of the central and most famous conclusions of Chomsky's (1957) foundational work in syntax is that linguistic representations are hierarchical and that the rules of grammar make reference to this hierarchal organization. Thus, a sentence like (13) is not just a string of words, but rather can be represented as being hierarchically organized, as shown in (4a-b) which are notational variants of one another.

(13) The man danced with the woman.

(14) a. [S [NP The man] [VP danced [PP with [NP the woman]]]]

b.



In addition, syntacticians have noticed that a broad range of seemingly disparate linguistic phenomena can receive a principled explanation if one assumes the notion of c-command, a structural relation defined over hierarchical structure. C-command, in turn, is defined as follows.

(15) x c-command y iff
a. x ≠y
b. Neither x dominates y nor y dominate x
c. The first branching node that dominates x also dominates y

A useful rule of thumb to calculate c-command without using the formal definition in (5) is to start with the element whose c-command domain one wants to calculate, go up in the tree structure to the first branching node, and then go down. Everything on the way down from the branching node is contained within the c-command domain of the element in question.

Thus, in our example in (3), the NP *the man* c-commands the VP, the PP and the NP *the woman*.

Hierarchical structure and c-command, in turn, each play a crucial role in the notion of scope. Scope can be illustrated using a simple mathematical analogy. Consider the mathematical expressions *2 x (3+5)* and *(2 x 3) + 5*. The scope of *2 x* (the number 2 followed by the multiplication sign) can be thought of as its domain of application. Thus, in *2 x (3+5)*, *(3 + 5)* falls within the scope of *2x*. In contrast, in *(2 x 3) + 5*, *3* falls within the scope of *2x* whereas *5* falls outside of its scope. Notice finally that different scope relations give rise to different results once the expressions are computed. We can now consider the notion of scope as it applies to language. Certain expressions, such as negation for example, are scope-bearing expressions. Scope, in turn, is defined in terms of the notion of c-command, as given in (16).

(16) Scope principle: an expression α takes scope over an expression β iff α c-commands β.

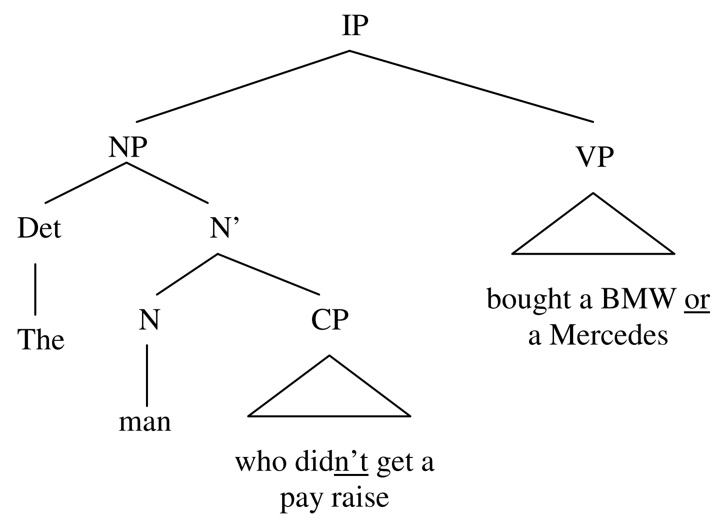
Retuning to the interpretation of *or* with respect to negation, we can now say that *or* receives a conjunctive interpretation – in other words, that De Morgan's law holds - if *or* falls within the scope of negation; that is, if it falls within the c-command of negation. We can now return to the examples in (11) and (12), repeated here as (17), and see that negation, which is too deeply embedded within the subject NP does not c-command *or* in (17a) but that it does c-command *or* in (17b). This explains why only (17b) obeys DeMorgan's law. The reader can verify that for himself/herself by looking at the tree diagrams provided in (18a) and (18b) and applying the rule of thumb (or the formal definition) given for c-command. Readers unfamiliar with X-bar terminology need not worry about the labels.

What matters here is the structure of those sentences and the fact that negation either c-command or fail to c-command *or*.

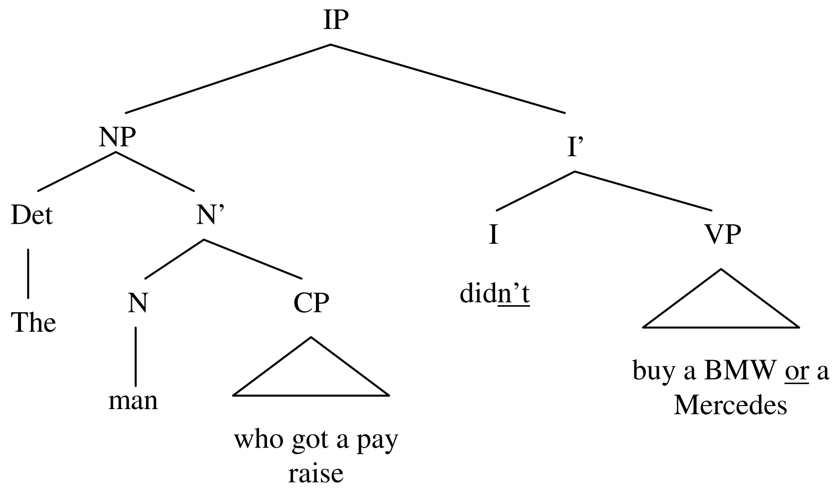
(17) a. [IP [NP The man who didn't get a pay raise] [I' [VP bought a BMW or a Mercedes]]]

b. [IP [NP The man who got a pay raise] [I' didn't [VP buy a BMW or a Mercedes]]]

(18a)



(18b)



To recap, negation, a downward-entailing operator, can interact with disjunction, *or*, to give rise to a pattern of entailment relations known as DeMorgan's laws of propositional logic. Whether or not the interpretation of negation and disjunction is subject to DeMorgan's laws, in turn, depends on the kind of syntactic relation holding between these two elements. Specifically, for DeMorgan's law to hold, *or* must occur in the scope – i.e., the c-command domain – of negation.

Another important property of the theoretical notions described above is that in addition to explaining what mature speakers know about English (and other languages as well, of course), these principles have also been shown to explain what young children know about English and thus why the course of language development does not vary arbitrarily. There is a large literature on this topic, spanning several decades, including a number of introductory books, for example, Crain and Thornton, (1998); Crain and Lillo-Martin, (1999) and Guasti, (2001). In addition, many experimental studies have uncovered knowledge of the very principles discussed above in young children. For syntactic structure, see for example Lidz et al. (2003); Crain, (1991); Crain and Nakayama, (1985); and Lidz and Musolino, (2002);

among many others. For knowledge of c-command in young children, see Crain (1991), Lidz and Musolino, (2002); Crain et al. (2002). For entailment relations, see Noveck, (2001); Papafragou and Musolino, (2003); Musolino and Lidz, (2006). And finally for knowledge of DeMorgan's laws in preschoolers, see Gualmini and Crain, (2002); Crain et al., (2007); Crain et al. (2002) and Minai, Goro, and Crain (2006).

To illustrate these conclusions with a concrete example, consider the study by Lidz and Musolino (2002). These authors asked how adult and child speakers of English interpret scopally ambiguous sentences such as *The Smurf didn't catch two birds*. Notice that on one reading this sentence can be paraphrased as meaning that it is not the case that the Smurf caught two birds – maybe she caught only one. Here, the phrase *two birds* is interpreted within the scope of negation. Alternatively, one could interpret that sentence as meaning that there are two specific birds that the Smurf didn't catch. In this case, the phrase *two birds* would be interpreted outside the scope of negation. What Lidz and Musolino (2002) showed is that typically developing 4-year-olds differ from adults in that they display a strong preference for the reading in which *two birds* is interpreted within the scope of negation. In order to determine whether children's behavior was constrained by the linear order of negation and *two birds* or by the c-command relations holding between these elements, Lidz and Musolino tested 4-year-old (and adult) speakers of Kannada, a Dravidian language in which, because of differences in word order, linear order and c-command relations are not confounded, as they are in English in this case. What Lidz and Musolino (2002) found is that 4-year-olds are constrained by the c-command relations holding between the quantificational elements – not their linear order. This shows that abstract and independently motivated notions such as c-command can be used to explain developmental patterns.

4. Experiment

In the following experiment, we propose to assess (a) semantic knowledge of the basic truth conditions associated with negation and disjunction (*or*) as well as core semantic notions such as entailment relations and DeMorgan's laws of propositional logic; (b) knowledge of core syntactic notions, namely scope and c-command and finally, (c) the relationship between (a) and (b). In order to test knowledge of (a-c), we have chosen an experimental technique which has proved to be very successful in assessing (typically developing) children's interpretation of a broad range of complex linguistic constructions, often involving ambiguous sentences and intricate interactions between logical expressions, including some of the notions and principles under investigation in the present study (Musolino, Crain and Thornton, 2000; Lidz and Musolino, 2002; Musolino and Lidz, 2003; Musolino and Lidz, 2006). This technique is called the Truth Value Judgment Task (TVJT) (Crain and Thornton, 1998).

It is worth pointing out that there is now solid evidence that children as young as 4 experience no difficulty with the TVJT and that they are capable of giving either Yes or No answers when appropriate, including appropriate justifications for their answers. Moreover, the TVJT has now been used successfully to test young children's knowledge of complex linguistic constructions in different languages, including English (Musolino, 2004), Greek (Papafragou and Musolino, 2003), Kannada (Dravidian) (Lidz and Musolino, 2002) and Korean (Han, Lidz and Musolino, 2007). Finally, the TVJT has recently been used to uncover complex grammatical knowledge in WS (Zukowski, 2001). In our experiments, we will show that knowledge of the facts in (a-c) can be assessed by asking participants to judge sentences containing the various expressions under investigation in a range of configurations corresponding to the different interpretations that such sentences give rise to.

Participants

Participants included four groups of 12 individuals: a group of individuals with WS (6 males and 6 females) (mean age = 16;4 (year, month), SD = 11.07 months, age range = 11;10-21.11), a group of typically developing children matched to the WS group on the basis of mental age (MA) (6 boys and 6 girls) (mean age = 6;1, SD = 3.3 months, age range = 5;2-7;8), a group of typically developing 4-year-olds (5 boys and 7 girls) (mean age = 4;3, SD = 3.7 months, age range = 4;0-4;11), and a group of 12 typical adult speakers of English (7 females and 5 males).

The WS individuals all received a positive diagnosis using a FISH (fluoride in situ hybridization) test (Ewart et al., 1993). WS and MA individuals were matched using raw scores on the non-verbal subtest of the Kaufman Brief Intelligence Test (KBIT; Kaufman & Kaufman, 1990). This test is a standardized IQ test that has relatively few spatial items, and hence does not unfairly penalize people with WS for their severe spatial deficit. Mean raw scores for the non-verbal subtest of the KBIT were 21.66 (SD = 1.22) for people with WS and 20.5 (SD = 1.39) for the MA matched children. Mean raw scores on the verbal subtest were 41.4 (SD = 1.88) for the WS group and 33.75 (SD = 1.03) for the MA controls. The higher verbal scores for the WS group was expected, as vocabulary level in people with WS typically increases beyond overall non-verbal mental age by adolescence[5].

The WS IQ profile was typical with a mean IQ of 62.75 (SD = 4.19) on the KBIT, (compared to mean = 118.5, SD = 2.44 for the MA group). In addition, the profile was typical in showing severe spatial impairment, reflected in scores below the 3rd percentile for age on a standardized block assembly task (Differential Abilities Score; Elliot, 1990).

[5] The verbal subtest is composed of a vocabulary test in which people must name pictured targets, and a reading test in which they must complete a partial word on the basis of a "definition" that is given by the experimenter. It does not include any measure of syntax.

Individuals with WS were recruited through the Williams Syndrome Association, and MA controls through local preschools in the Baltimore, MD area. Typically developing 4-year-olds were recruited at preschools in the Baltimore, MD area and in the Bloomington, IN area. Finally, the adults were all undergraduate students at Indiana University.

Design, Materials, and Procedure

Participants watched short computer-animated vignettes and heard recorded spoken sentences that described the vignettes. They then made judgments of the truth value of each sentence ("right" or "wrong") in the context of the vignette. Interpretation of sentences varied depending on the syntactic structure and inclusion of negation and the disjunction operator, *or*.

The design included two experimental and four control conditions, which isolated the components of the experimental conditions. In the two experimental conditions, participants were tested on their interpretation of sentences like (19) and (20). Both sentences involve a subject NP which contains a relative clause, both contain negation and both contain the disjunction operator, *or*. The crucial difference between (19) and (20) is whether *or* occurs in the scope, i.e. in the c-command domain of negation (see section 2). In examples like (19), negation both precedes and c-commands *or* whereas in examples like (20) negation precedes – but does not c-command – *or*. Thus, sentences like (19) and (20) were used to determine whether participants have knowledge of the way that negation and disjunction interact in syntactic contexts where negation either merely precedes, or both precedes and c-commands *or*. In both examples, we held constant the number of words intervening between negation and *or*, namely four.

(19) The cat who meows will not be given a fish or milk.

(20) The owl that does <u>not</u> hoot will get bugs <u>or</u> a mouse.

Notice now that the difference in c-command relations between negation and *or* in the examples above gives rise to opposite truth conditions for sentences like (19) and (20). Truth conditions are simply the set of circumstances under which a sentence is true or false.

<u>Table 1</u>

	If given a fish or milk	If given something else
<u>C-Command</u> The cat who meows will not be given a fish or milk	False	True
<u>Precede</u> The cat who does not meow will be given a fish or milk	True	False

The four control conditions isolated each of the elements that interacted in the experimental sentences. Specifically, being able to correctly calculate the truth conditions of sentences like (19) and (20), also involves understanding (a) the meaning of *or*, (b) the meaning of negation, (c) knowing about De Morgan's laws, and (d) being able to parse a relative clause. Thus, our four control conditions were designed to independently test for knowledge of (a-d).

Participants were therefore tested in a total of 6 conditions (2 experimental conditions, namely 'precede' and 'c-command', and 4 control conditions, namely 'or', 'negation', 'De Morgan' and 'relative clause'. See appendix 1 and 2 for a complete list of statements).

In each of the 6 conditions, participants were asked to judge the truth of 8 different statements; for example, 8 statements in which negation only precedes *or*, 8 statements in which negation precedes and c-commands *or*, etc. Of these 8 statements, 4 were true and 4 were false. This was achieved by creating true and false outcomes for each vignette/

sentence combination (see Appendices for details). The 6 conditions by 8 statements yielded a total of 48 statements to be judged, 24 true and 24 false.

Four lists of 48 statements were created in which the two sets of experimental statements (precede and c-command) were blocked and the control statements were randomly interspersed throughout the blocks. In two of the lists, the set of 'c-command' statements appeared first and in the other two, the set of 'precede' statements appeared first. Participants were randomly assigned to a list, but WS individuals were assigned to the same list as their MA control.

All vignettes were created and animated using Microsoft PowerPoint software and they were displayed on a computer monitor. A prerecorded female voice described each vignette as events unfolded, and at the end, a statement describing the outcome of each vignette was made (see appendix 1 for sample context). The participants were told they would watch the vignette and hear a voice saying something, and their task was to determine whether the voice was 'right' or 'wrong'. The task was identical for participants in all four groups. Adult participants were told that the task was designed for use with young children and mentally retarded individuals and that their responses would be used to generate a baseline for performance in these other groups.

Results

In the analyses below, our dependent measure is the percentages of correct responses. Table 2 summarizes the data and provides the percentages of correct responses for each of the four groups in all six conditions. In addition, we provide, for each group, the mean percentages of correct responses collapsed over the two experimental and the four control conditions.

<u>Table 2</u> **Percentages of correct responses**

	Experimental conditions			Control conditions				
	Precede	**C-command**	**Mean Exp.**	**Neg**	**Relative**	**Or**	**De Morgan**	**Mean Control**
Adults	97.9% (SD 7.2%)	100%	**99.4%**	100%	100%	100%	100%	**100%**
WS	77% (SD15.8%)	75% (SD 22.6%)	**76%**	86.4% (SD 16.3%)	96.8% (SD 7.7%)	93.6% (SD 11.5%)	86.4% (SD 14.5%)	**90.8%**
MA Matches	87.5% (SD 13%)	91.6% (SD 18.7%)	**89.5%**	93.7% (SD 11.3%)	95.8% (SD 8.1%)	94.7% (SD 8.3%)	93.7% (SD 15.5%)	**94.5%**
4-year-olds	60.4% (SD 20.5%)	64.5% (SD 19.8%)	**62%**	84.3% (SD 17.7%)	90.6% (SD 12%)	80.2% (SD 18.8%)	82.2% (SD 16.4%)	**84%**

Adult participants performed at (or close to) ceiling on both experimental and control conditions, showing that our method is capable of tapping linguistic knowledge in this domain. We do not consider their data further.

Recall that our principal question is whether individuals with WS interpret sentences containing *or* and *negation* in ways that require that they engage core properties of the computational system of language (e.g., scope, c-command). Thus, the relevant data here are the absolute levels of performance of individuals with WS, with the assumption that one simply cannot interpret the key sentences appropriately at levels above chance without engaging these properties[6]. Accordingly, we compared performance levels on both the experimental and control conditions against chance performance (i.e. 50% acceptance rate).

[6] Indeed, recall that the sentences in our two experimental conditions are very similar to one another in that they both contain a relative clause, *or*, and negation (e.g., *The cat who meows will not be given a fish or milk* (c-command) and *The dog who does not bark will get bones or French fries* (precede)). Consequently, in order to correctly calculate the truth conditions of each sentence, one must take into account their structure – as opposed to a mere list of the lexical items they contain - and thus be sensitive to notions such as scope and c-command (or their theoretical equivalent).

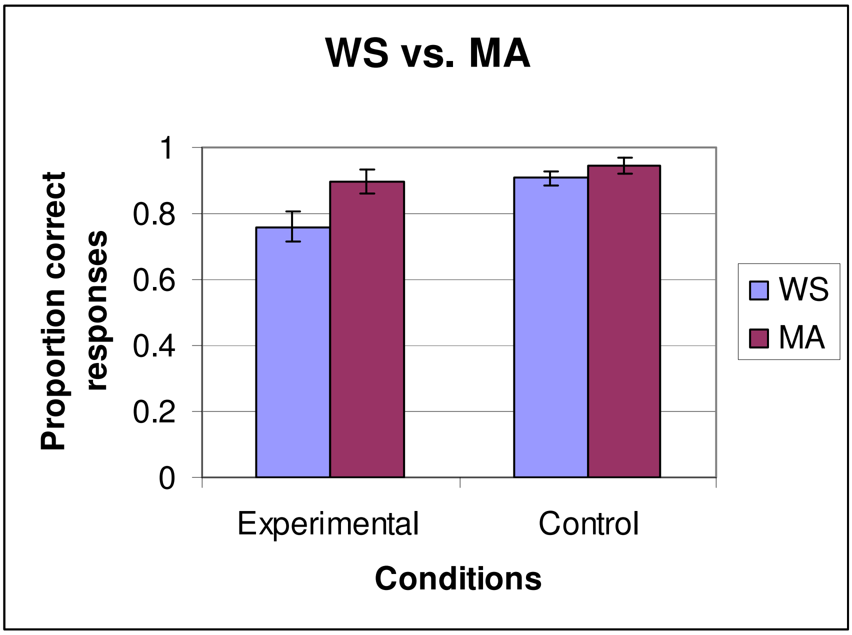
For each experimental and control condition, we found that individuals with WS performed significantly above what would be expected by chance (all ps $< .01$).

Next, we turn to our secondary question, namely how the performance of individuals with WS compares to that of neurologically normal individuals. In order to address this question, we analyzed the proportions of correct responses using a 3 (group: WS, MA, 4-year-olds) by 2 (conditions: experimental vs. control) mixed design ANOVA. The analysis revealed a main effect of group ($F(2, 33) = 9.05$, $p< 0.01$), a main effect of condition ($F(1,33) = 50$, $p < 0.001$), and a significant interaction between group and condition ($F(2,33) = 6.28$, $p < 0.01$).

In order to compare the performance of our group of WS individuals to that of children matched for MA, we began by considering the performance of our MA group against chance levels. We found that this group, like WS, performed significantly above chance on each experimental and control condition (all $p < .001$). We then compared WS and MA using a 2(group: WS vs. MA) by 2(conditions: experimental vs. control) mixed design ANOVA. The analysis revealed a main effect of group ($F(1, 22) = 4.12$, $p = 0.05$), a main effect of condition ($F(1,22) = 23.07$, $p < 0.001$), and a significant interaction between group and condition ($F(1,22) = 5.66$, $p < 0.05$). Thus, overall, MA performed better than WS, the control conditions yielded a higher proportion of correct responses compared to the experimental conditions, and the difference in performance between WS and MA was larger in the experimental conditions than in the control conditions.

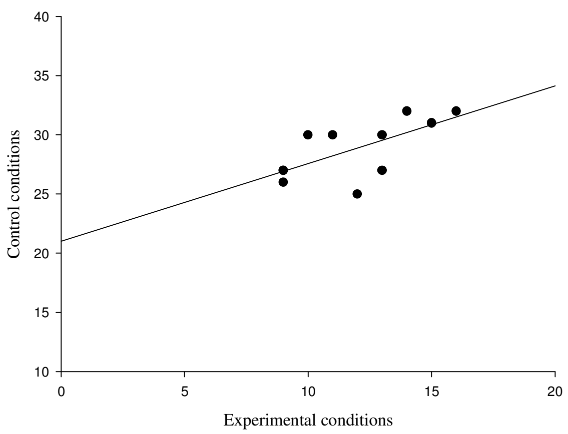
To further analyze these effects, we ran separate ANOVAs to compare WS and MA on the two sets of conditions, namely experimental and control. For control conditions, a 2 (group: WS vs. MA) by 4 (condition: negation, or, De Morgan and relative clause) mixed design ANOVA was performed on the proportions of correct responses. The analysis revealed no significant main effect of group ($F(1, 22) = 1.40$, $p = 0.24$), no significant main effect of condition ($F(3, 66) = 1.99$, $p = 0.12$) and no significant interaction between group and condition ($F(3, 66) = 0.91$, $p = 0.43$). To compare performance on the experimental conditions, a 2 (group: WS vs. MA) by 2 (condition: precede vs. c-command) mixed design ANOVA was performed on the proportions of correct responses. The analysis revealed a significant main effect of group ($F(1, 22) = 5.32$, $p < 0.05$), no significant effect of condition ($F(1, 22) = 0.057$, $p = 0.81$) and no significant interaction between group and condition ($F(1, 22) = 0.51$, $p = 0.48$). In other words, there were no reliable differences between the WS individuals and MA matches on any of the control conditions, but there was overall poorer performance on the experimental condition among people with WS (see graph 1)

Graph 1

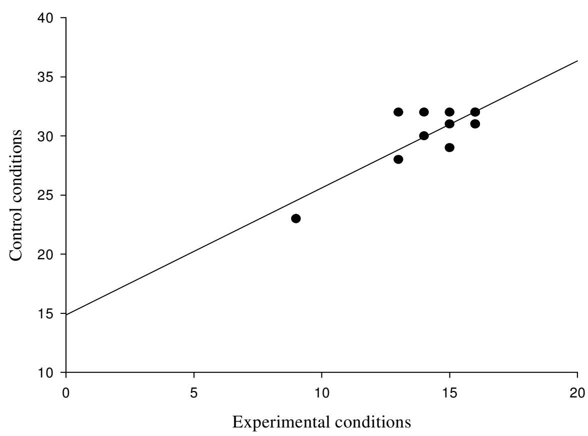


In order to refine our comparison between WS and MA, we asked, in separate analyses, the extent to which performance on the control conditions, for each individual in these two groups, would predict performance on the experimental conditions. Since performance on the experimental conditions is in part a function of what participants know about each of the separate components tested in the control conditions, we thought that this analysis might point to particular pockets of weakness in the control conditions that might predict overall performance in the experimental conditions. In order to do this, we computed, for each individual in both groups, an experimental score (which is an average of performance over the two experimental conditions) and a control score (which is an average of performance on the four control conditions). We then tested for correlations between the two scores. We found significant correlations between these two scores for both groups, r = 0.68, p = 0.014 for WS, and r = 0.82, p = 0.001 for MA. Thus, for each group, the level of difficulty experienced in the control conditions is significantly related to the level of difficulty experienced in the experimental conditions (see graphs 2 and 3).

Graph 2: WS group



Graph 3: MA controls



Given this finding, one possible explanation for the fact that WS and MA differ only in the experimental conditions, is that the compounding effect of having to interpret sentences which contain negation, disjunction and a relativized subject – as opposed to having to interpret these components one at a time in the control conditions - leads to more processing difficulties for WS than for MA. To further investigate this question, we used a multiple regression analysis (stepwise) to assess the contribution of each of the control variables to overall performance in the experimental conditions. Recall that the components interacting in the experimental conditions are negation, disjunction and a subject containing a relative clause. Accordingly, the control conditions were designed to assess performance on each of these components independently, so we have four control conditions: negation, disjunction, relative clause, and DeMorgan. The fourth control condition, DeMorgan, was included to check participant's knowledge of DeMorgan's laws in simpler sentences which do not contain a relative clause. Thus, DeMorgan is really a combination of 'negation' and 'disjunction'. The idea here is to determine the relative importance of each of these interacting components to overall performance on the experimental conditions.

For people with WS, the regression model kept the variables 'negation' and 'DeMorgan' as significant predictors ($p = 0.01$ and $p < 0.001$, respectively), with negation by itself accounting for 46% of the variance and negation combined with DeMorgan accounting for 66% of the variance. The other two variables, disjunction and relative clause, were rejected by the model. The fact that the model kept negation as a significant predictor of overall difficulty makes very good sense as it is well known in the psycholinguistic literature on sentence processing that negatives are typically associated with processing difficulty (see Horn, 1972 and references cited therein). For the MA matched children, the model also kept negation as a significant predictor ($p < 0.001$) accounting for 63.7% of the variance and it rejected disjunction and relative clauses. However, the model for MA also rejected DeMorgan. What is interesting to observe here though is that for the MA children the variables 'negation' and 'DeMorgan' were highly correlated, $r = 0.73$, $p < 0.01$ which suggests that these two variables account for redundant portions of the variance and probably explains why the model didn't keep them both. For the WS group however, 'negation' and 'DeMorgan' are uncorrelated, $r = 0.11$, $p = 0.36$. This difference suggests that while negation is associated with processing difficulty for both WS and MA, the interaction between negation and disjunction (i.e. DeMorgan) is associated with a different level of difficulty in the two groups. One way to interpret this result would be to speculate that whereas negation by itself gives rise to approximately the same level of processing difficulty for both WS and MA matched individuals, the combination of negation and disjunction is more difficult to process for people with WS compared to their MA matches.

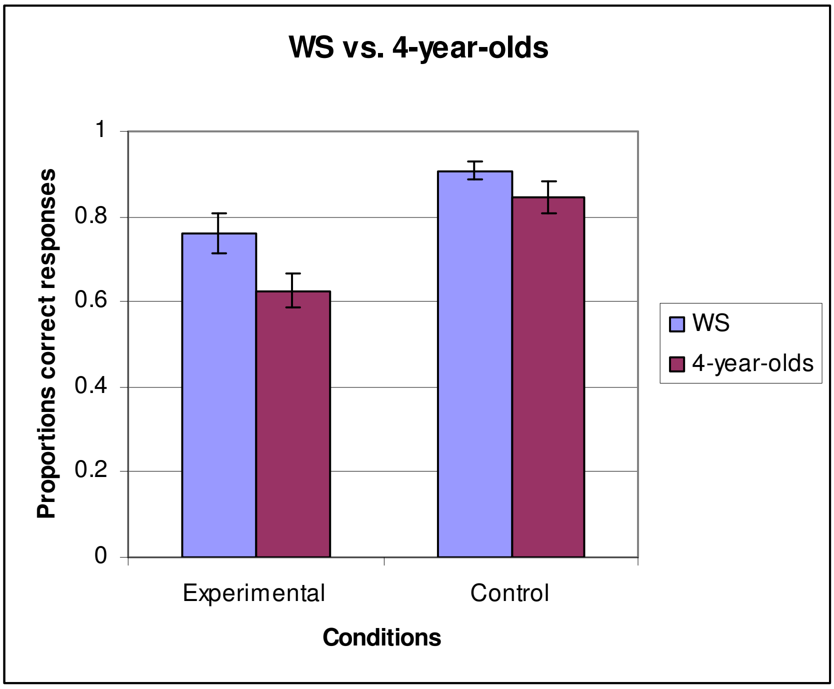
In sum, for both MA matched children and people with WS, performance on the control conditions is significantly related to performance on the experimental conditions. Moreover, in both cases, negation is a significant predictor of overall performance. Finally, the interaction between negation and disjunction seems to create more processing difficulty for people with WS than for the MA matched group. Put another way, people with WS can handle processing complexity – and therefore look like their MA matches – up to a certain critical threshold or 'tipping point' which, once crossed, leads the system into a crash – albeit a rather minor one in this case (recall that on average, people with WS responded correctly 76% of the time in the experimental conditions compared to 89.5% for the MA matched children).

If this is correct, we are predicting that individuals with less efficient processing skills, such as younger typically developing children for example (i.e., children younger than 6), should, like individuals with WS, experience more difficulty with the experimental conditions than the control conditions. In other words, we predict that typically developing 4 year-olds might show the same consequences of complexity as people with WS. Let us first examine the performance of our group of 4-year-olds on the experimental and control conditions. Beginning with the latter, we found that 4-year-olds performed significantly above chance on all four control conditions (all $p < .001$). This shows that younger children did not experience difficulty with the task and that they have knowledge of the meaning of the components interacting in the experimental conditions. On the experimental conditions, we found that 4-year-olds performed significantly above chance on 'c-command' ($t(11) = 2.54$, $p < .05$), but that performance on 'precede' was not significantly different from chance performance ($t(11) = 1.75$, $p = .10$)[7]. We also found that performance on the control conditions was uncorrelated with performance on the experimental conditions. This lack of correlation is most likely due to the fact that 4-year-olds are at chance on one of the experimental conditions.

Turning now to our prediction, we performed a 2 (group: WS vs. 4-year-olds) by 2 (condition: experimental vs. control) mixed design ANOVA on the proportions of correct responses. As expected, the analysis failed to reveal an interaction between group and condition ($F(1,22) = 1.74$, $p = 0.2$), but it revealed a significant main effect of condition ($F(1,22) = 44.85$, $p < 0.001$), and a significant main effect of group ($F(1,22) = 4.81$, $p < 0.05$). The main effect of condition reflected the difficulty of the experimental conditions relative to the control conditions; the main effect of group reflected better performance among people with WS than typically developing 4 year-olds (see graph 4).

[7] As pointed out by one of the reviewers, weak performance on the experimental conditions may suggest that the grammar of 4-year-olds is different from that of mature speakers.

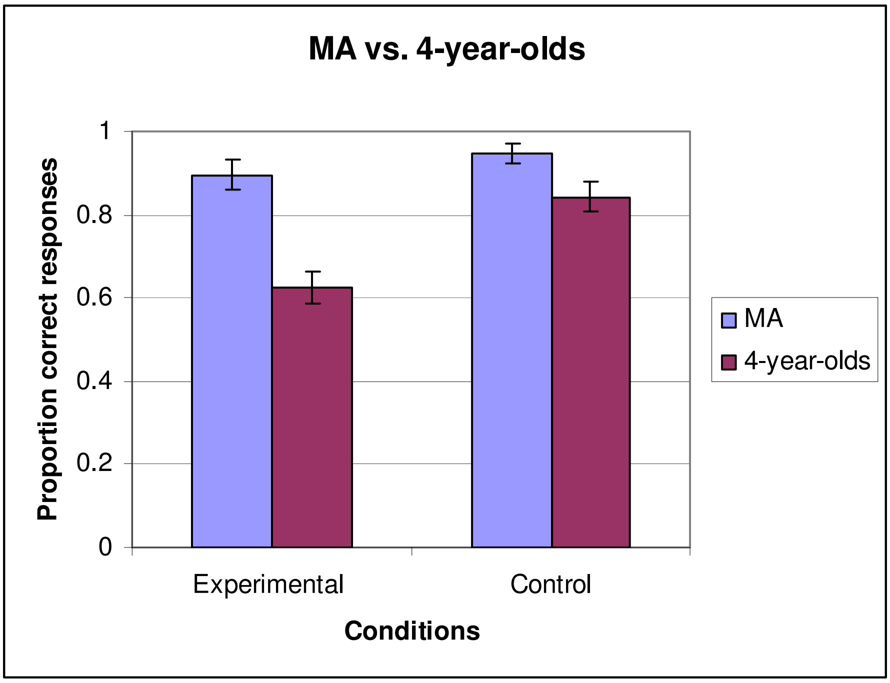
Graph 4



Recall that the same analysis comparing WS and MA revealed a main effect of group and a main effect of condition as well, but that it also revealed a significant interaction between group and condition, which is not found between WS and typically developing 4-year-olds. Thus, this pattern reveals the relative difficulty of the experimental conditions compared to the control conditions for both our WS and 4-year-old groups.

To the extent that the difference in performance between WS and 4-year-olds on the one hand, and MA matches on the other, reflects the greater complexity of the experimental conditions compared to the control conditions, we may also be able to observe this effect when comparing our two groups of typically developing children, namely MA and 4-year-olds. Put another way, we may expect that 4-year-olds would behave disproportionately worse than MA matches (i.e., 6-year-olds) on the experimental conditions compared to the control conditions. In other words, we would expect here, as in the case of WS vs. MA, to uncover an interaction between group and condition. To find out, we ran a 2 (group: MA vs. 4-year-olds) by 2(conditions: experimental vs. control) mixed design ANOVA. In addition to a significant main effect of group ($F(1,22) = 18.46$, $p<0.001$) and condition ($F(1,22) = 32.1$, $p<0.001$) reflecting the fact that overall, MA performed better than 4-year-olds, and that overall performance on the control conditions was higher than on the experimental conditions, the analysis also revealed a significant interaction between group and condition ($F(1,22) = 12.78$, $p<0.01$) (see graph 5)

Graph 5:



To recap, we uncovered a group by condition interaction when comparing the performance of WS and MA. That is, while WS and MA performance was on a par on the control conditions, WS performance was significantly below that of MA on the experimental conditions. Subsequent analyses suggest that this difference reflects the greater complexity of the experimental conditions compared to the control conditions coupled with the assumption that WS have more limited processing resources compared to MA. If so, we should be able to observe a developmental trend whereby younger participants ought to be more sensitive to the relative difficulty of the experimental conditions compared to the control conditions. This is indeed what we uncovered in subsequent analyses comparing WS with typically developing 4-year-olds, and 4-years-olds with MA (6-year-olds). Here we found that the group by condition interaction uncovered in the WS vs. MA comparison was no longer present when WS was compared to a younger group, i.e. 4-year-olds, but that the developmental effect reappeared when 4-years-olds were compared to MA.

Discussion

The first, important observation emerging from our results is the flawless performance of our adult participants. In addition to establishing the relevant benchmark against which to compare the performance of our three other groups (i.e. WS, MA, and 4-year-olds), this fact shows that the intuitions of linguists regarding the intricate syntactic and semantic behavior of logical operators such as negation and disjunction can be verified experimentally. Second, the overall excellent performance of the WS and MA groups-- with both groups performing well above chance on all conditions-- clearly indicates that these participants did not experience any difficulty with the task.

Let us now consider the implications of WS and MA performance on the control conditions. Recall that these conditions were designed to assess knowledge of the individual components interacting in the experimental conditions, namely knowledge of the basic set of truth conditions associated with negation, disjunction, as well as the logical laws regulating the interaction between the two (DeMorgan's laws). Overall performance for both groups on the control conditions was excellent (90.8% correct on average for people with WS and 94.5% for MA matched children) and no differences were found between the two groups. What this shows for people with WS is semantic knowledge of the basic truth conditions associated with negation, the disjunction operator, *or*, as well as knowledge of the logical laws regulating the interaction between the two.

The importance of this conclusion is worth stressing. In the case of *or*, near perfect performance (93.68% correct) shows that WS have a firm grasp of the logical function of the disjunction operator. In other words, they know that statements such as *John will get coffee or tea* are true if John gets either coffee or tea and false if he gets neither. Another way to say this is that individuals with WS know that *or* can receive what we called a disjunctive interpretation. Excellent performance on the DeMorgan control (86.46% correct) shows that individuals with WS also have a firm grasp of what happens when the disjunction operator interacts with negation. Specifically, they know that a statement like *John didn't have coffee or tea* is true if John had neither but false if he had either tea or coffee. In other words, individuals with WS know that when *or* occurs in the scope of negation, it receives a conjunctive interpretation. As we shall now see by looking at what happened in the experimental conditions, individuals with WS also know that *or* receives a conjunctive interpretation only when it occurs in the c-command domain of negation, but not otherwise.

Turning to performance on the experimental conditions then, two interesting observations emerge. The first is that WS performance on these conditions was quite good (77.08 % correct for 'precede' and 75% correct for 'c-command) and in both cases significantly above chance. This shows that individuals with WS know that the interaction between negation and disjunction gives rise to the pattern of entailment relations described by DeMorgan's laws *only* when disjunction occurs in the c-command domain of negation. Put another way, individuals with WS know that the truth conditions associated with sentences containing negation and disjunction differ depending on whether disjunction falls within the c-command domain of negation (see Table 1). People with WS thus know about scope and c-command as well as their semantic consequences for the interpretation of negation and disjunction. The second noteworthy observation is that, WS performance in the experimental conditions (but not the control conditions) is slightly lower than that of MA controls. We come back to this observation in the next section.

5. General discussion

To recap, we investigated knowledge of core syntactic and semantic principles in individuals with WS. Specifically, we have been concerned with (a) fundamental syntactic relations (scope and c-command) (b) fundamental semantic relations (entailment relations and DeMorgan's laws of propositional logic), and (c) the relationship between (a) and (b). Our main question has been whether such grammatical structure is present in WS. Our results demonstrate that individuals with WS interpret sentences of English in ways that require the presence of the grammatical structure/principles in (a-c). Because these principles represent core aspects of the computational system of language, i.e. rule-like operations governing the structure and interpretation of sentences, our results are compatible with approaches which predict such knowledge to be present and engaged in WS (i.e., modularity and the conservative hypothesis), but they raise a serious challenge to the neuroconstructivist view, which predicts qualitative differences in the system of knowledge underlying linguistic abilities in WS compared to typically developing individuals.

In the following discussion, we elaborate on these conclusions, framing the issues in a broader context, and addressing potential objections. First, we consider the nature of the challenge to neuroconstructivism posed by our results. This is done through a discussion of the notion of 'selective sparing' – a key point of contention between the rival theories under consideration. To this end, we distinguish two versions of the neuroconstructivist thesis: a strong and a weak one. We then show that the strong thesis is empirically untenable, and that the weak one is at best orthogonal to the issue of modularity. Having shown that our results are incompatible with neuroconstructivism, we then consider their implications for modularity and the conservative hypothesis. Finally, we turn to our secondary question, namely how the performance of individuals with WS compares to that of neurologically normal individuals.

5.1. Neuroconstructivism and 'selective sparing'

Recall from section 2 that one of the key points of contention between the modular and neuroconstructivist views hinges on whether grammar is 'intact' or 'selectively spared' in WS (see Zukowski, 2001 for relevant discussion). The first step toward a productive resolution of this question is to try to understand exactly what is meant by 'selective sparing'.

Let us begin with a distinction that both parties to this debate routinely make, namely the difference between, on the one hand, behavioral levels on a given task, and, on the other hand, the underlying cognitive abilities which enter into the relevant behavior. That this distinction is indeed made by both parties can be seen from the following quotes from Karmiloff-Smith (1998), " … even when normal *behavioural* levels are found in a developmental disorder in a given domain, they might be achieved by different *cognitive* processes [her emphasis]" (p.391), and from Zukowski (2004), "It is relatively easy to quantify performance on tests of language. A more difficult task is translating a pattern of performance into conclusions regarding the linguistic abilities/mechanisms that underlie that performance" (p.1). Given this distinction, we can interpret the phrase 'intact/spared language' in two ways. We can either decide that 'intact/spared' applies to the pattern of *behavior* on a given task, or, alternatively, that it applies to the *cognitive structures* underlying such behavior. Our primary claim concerns the latter, in particular whether grammatical *knowledge* is intact or spared.

The next issue is to decide how to evaluate whether grammatical knowledge is spared or not. Typically in the study of WS (as well as other developmentally atypical populations), scientists compare the performance of the target group to some other control group. There are choices to make here, as we alluded to in our introduction. If we decide that the right control group is unimpaired individuals of the same chronological age, then this is perhaps setting the bar too high, since people with WS are usually moderately retarded. As a consequence, scientists often choose to compare individuals with WS to individuals who are matched on mental age, as we have done here. Indeed, this matching method is one of the most common ones in the study of language (and other cognitive capacities) in people with WS; hence a common way to interpret the question of 'selective sparing' involves the relationship between language ability and mental age. As Zukowski (2001: 4) explains "By selective sparing what is usually meant is that language performance is better than one would expect on the basis of overall mental age …". But choice of such control groups as the basis for deciding whether grammatical knowledge is spared or not is a mixed bag: Karmiloff-Smith (1998:395) articulates the problem as follows: "To state that a person has fluent language but an IQ of 51 indeed appears theoretically surprising and could lead to the conclusion that syntax develops in isolation from the rest of the brain. But to state that the same person has fluent language and an MA [mental age] of 7 yrs changes the conclusion." This conclusion is echoed by Brock (2006:13) " … comparison with data from typically developing children indicate that their [i.e. WS] grammatical abilities are no better than one would predict on the basis of overall cognitive abilities …".

In sum, we can define ‘selective sparing’ in the following three ways:

Selective sparing:

Grammar is selectively spared in WS if:

(a) *Grammatical knowledge* is present and has the same structure as posited in the typical, mature system, or

(b) *Behavioral* levels on language tasks are at least as good as those of the relevant comparison group, or

(c) *Behavioral* levels on language tests exceed what one would expect on the basis of mental age[8].

With the above distinctions in mind, we can now think of two versions of neuroconstructivism: a strong and a weak one. The strong version would hold that grammar isn't ‘selectively spared’ in WS because (a) isn't true. The weak version would claim that grammar isn't spared in WS because either (b) or (c) (or both) is/are false.

Let us begin with an examination of the strong version of neuroconstructivism. As currently formulated, neuroconstructivism indeed makes claims about the nature of grammatical *knowledge* in WS, both explicitly and implicitly. Indeed, based on what Karmiloff-Smith and colleagues write, this conclusion is difficult to escape: “The results of the two present studies … challenge the often-cited claim that the particular interest of Williams syndrome for cognitive science lies in the fact that *morphosyntactic rules* [our emphasis] are intact.” (p.257). Or, to take another example, this time from Thomas and Karmiloff-Smith (2003), “The final semantic and conceptual *representations* [our emphasis] formed in individuals with WS appear to be shallower, with less abstract information and more perceptually based detail …” (p. 652).

[8] Notice that (c) can be seen as a special case of (b).

The problems with the strong version of neurconstructivism should now be obvious: first, it is empirically falsified, at least within the confines of the phenomena under investigation. To be sure, our central empirical conclusion that the grammar of WS individuals is governed by the same abstract principles that characterize typically developing and mature systems flies in the face of any claims that grammar is either not present or abnormally structured in WS. Moreover, the strong neuroconstructivist thesis is theoretically implausible. This weakness comes from the repeated contention that WS individuals go about the task of language acquisition using different *cognitive* mechanisms, or that they are unable to extract underlying regularities or form linguistic generalizations (see section 2.2. for specific quotes and also Clahsen and Almazan, 1998 for related discussion).

If so, it would be astonishing, to say the very least, that individuals with WS end up constructing grammatical systems which are as complex and abstract as those found in typically developing individuals. All the more so when one learns that these 'different' cognitive mechanisms are good auditory memory, or good rote learning abilities. Short of a precise demonstration of how one would converge on the abstract notion of say, c-command (see section 4), simply by virtue of possessing good hearing skills or a large memory, such claims are devoid of any explanatory force. If anything, the default expectation should be that if good hearing or a powerful memory is what individuals with WS rely on when learning language, the grammatical systems that they end up building should be massively different from those found in typically developing individuals.

Let us now turn to what we called the weak version, beginning with the idea that 'intact/spared' applies to *behavioral* levels, instead of grammatical *knowledge* (see (b) above). In our mind, this option is a non-starter. To see why, suppose that we were to indeed decide that behavioral levels constitute the relevant criterion. If so, we would conclude that population X, compared to control population Y, has 'impaired grammar/language' to the extent that behavioral levels on some relevant language task are not as good in population X as they are in population Y. On this view, an anti-modularity argument would take the following form: individuals with WS often show *behavioral levels* on language tests that are not as good as those seen in mental age controls. Therefore language/grammar in WS is not intact/ spared. Therefore, modularity must be wrong. The problem with such an argument is that what is under attack here is a straw version of modularity. To be sure, differences in behavioral levels are in fact *perfectly compatible* with modularity. This is because the modularity thesis, a child of the cognitive revolution and the computational theory of mind, is a claim about *mental* architecture and operations, and thus only *indirectly* a claim about the nature of behavior itself. Thus, from a mentalistic perspective, differences in levels of behavior are, in and of themselves, uninformative, because they leave open the crucial question of what caused such differences in the first place. To quote Zukowski (2004), " … poor performance can be caused by many things: deviant or missing knowledge, parsing difficulty, memory overload, etc." (p.1). In sum, we may decide to chose behavioral levels as the relevant criterion in defining what counts as 'intact/impaired' language, but by doing so, we would ensure that our claims have no substantive bearing on the question of modularity.

Finally, let us consider the idea that we should talk about 'spared' grammar only to the extent that performance on language tests exceeds what one would expect on the basis of overall mental age (option (c) above). As Zukowski (2001) points out, there are some serious problems with such an approach. The first is that trying to settle the issue in this fashion yields different answers depending on one's choice of the mental age-matched comparison group. Indeed, if the MA-matched group is also mentally retarded (e.g., Down Syndrome), then WS language does surpass what one would expect based on MA. On the other hand, when the control group isn't mentally retarded (e.g., typically developing children), then language in individuals with WS typically does not exceed MA-based expectations. To further complicate matters, there is evidence suggesting that WS language does not exceed MA-based expectations in early childhood, but that it does so in late childhood and in adulthood (Jarrold, Baddeley, and Hewes, 1998).

As Zukowski (2001) points out, the remarkable fact about WS is how good their language is *given their level of mental retardation*. Indeed, nobody denies that WS displays, to use Karmiloff-Smith's own phrase "a verbal advantage over non-verbal intelligence". Crucially, such a language 'advantage' is simply not found in populations with similar levels of mental retardation (e.g., Down Syndrome), as has been amply demonstrated (e.g., Fowler, Gelman, and Gleitman, 1994). It follows that one simply cannot predict language ability on the basis of overall intelligence or other non-linguistic cognitive factors; a fact which, if anything, lends credence to the conclusion that language is independent from other aspects of cognition, and thus to some interesting degree modular.

In sum, we believe that (a) is the crucial question for cognitive scientists, and certainly for debates over modularity, whereas (b) and (c) are simply red herrings. Moreover, we contend that the claims made by proponents of neuroconstructivism regarding WS as it pertains to the broader issue of modularity end up failing for the following reasons: First, the strong version is theoretically implausible, and empirically falsified by the results of our study (see Brock, 2007 for a similar conclusion). Second, the weak version is at best orthogonal to the issues at stake because it argues against a straw version of modularity.

Finally, it bears emphasizing that we are not rejecting neuroconstructivism *en bloc*. To be sure, as discussed in section 2.2, neuroconstructivism makes a number of claims and suggestions, some of which we certainly agree with (e.g., adopting a developmental perspective; ultimately looking for lower-level underlying causes in the case of developmental disorders) and others pertaining to broad, foundational questions that fall far beyond the scope of the present article (e.g., nativism, constructivism, connectionism, etc.). What we are taking issue with here, as already discussed, are the empirical and theoretical claims made by neuroconstructivism *as it pertains* to WS.

5.2. Possible objections

In the discussion below, we consider potential objections that could be raised against the conclusion we draw from our results, as well as its implications for the neuroconstructivist approach. One possible objection would be to argue that the neuroconstructivist view does not make the kinds of predictions that we ascribe to it. However, such a position would be very hard to defend. Consequently, this objection can be easily dismissed. Specifically, recall that the neuroconstructivist view has been presented as an alternative to the modular view – or the "strict nativist" view to use Karmiloff-Smith's 1998 phrasing – and that it contains explicit claims that (a) knowledge of grammar (syntax and morphosyntax) is compromised in WS and (b) that grammar is learned in different ways by WS compared to typically developing children. In this regard, it is instructive to consider the logic of the neuroconstructivist view more carefully.

On the one hand, Karmiloff-Smith and colleagues use results such as those presented in Karmiloff-Smith et al. (1997) – bad performance on the part of WS individuals on some language tasks, relative to typically developing children - to show that WS grammar is indeed *not* "intact". On the other hand, Karmiloff-Smith (1998) argues that good performance on a behavioral task cannot be taken to infer "intact" knowledge, as success in such cases may have been achieved via different cognitive mechanisms. To quote Karmiloff-Smith (1998) "

… even when normal behavioral levels are found in a developmental disorder in a given domain, they might be achieved by different *cognitive* processes. This turns out to be the case for Williams syndrome, in which face processing and language are particularly proficient … but the proficiency seems to be achieved through different cognitive processes." (p.391).

Let us consider for a moment the possibility that good performance on our tasks was indeed achieved via mechanisms other than c-command, entailment relations, or DeMorgan's laws. What would those mechanisms be? The answer is quite simple: nobody knows. One could of course point to notions such as 'good auditory memory' or 'rote learning' but their role in constructing any language system is rather vague to say the least, and thus is devoid of any explanatory force. To be sure, the suggestion that good hearing or efficient memorization by themselves could lead to abstract generalizations such as c-command or DeMorgan's laws is about as informative as the claim that language acquisition can be explained by assuming that children have a 'strong desire to communicate' (which is surely true, but *not* an explanation). Notions such as scope, c-command, or DeMorgan's laws are not only *precise* but they are also *independently* motivated, and thus *explanatory*, as discussed earlier. Therefore, it would make little sense to abandon the account proposed here simply because of a claim that there may exist yet-to-be-defined mechanisms which would count as an alternative (for a broader criticism of constructivism, see Marcus, 1998).

A related objection would be to argue that we did not strictly speaking demonstrate that say, knowledge of scope and c-command, were the reasons individuals with WS correctly interpreted sentences like *The cat who meows will not be given a fish or milk* and *The owl that does not hoot will get bugs or a mouse*. Perhaps the relevant principle here is something like 'interpret *or* in the scope of negation and thus apply DeMorgan's laws if *not* and *or* occur in the same clause" or "do so if *or* directly precedes the word *fish* but not the word *bugs*" or any one of a myriad of logically possible principles. Such an approach would need to be taken seriously *only if* there indeed were reasons to believe that such putative principles actually do any independent work other than serving as possible counterexamples to our explanation. Again, this approach has no force. As Spelke (1998) reminds us "The requirement that claims of cognitive competence be proved by the elimination of every alternative claim, however implausible and unsupported, sets an impossible standard for research on cognition …" (p.190). In sum, because the principles that we invoked to explain our data are independently motivated, putative alternatives would have to do a lot of work indeed before they can count as serious competitors.

Finally, we turn to potential weaknesses of our empirical study pointed out by one of the reviewers. The first is that our sample size - 12 individuals with WS - is too small to generalize to the entire WS population. Moreover, our 12 participants span a 10-year age range (11;10 to 21;11). While it is true that a larger sample size would have given us a better sense of the variation found in the WS population, we do not believe that our conclusions are affected by the use of a smaller sample size. To be sure, we have shown that having WS does not necessarily lead to the construction of impaired or deviant grammars, as claimed by Karmiloff-Smith (1998). That is, we have shown that it is possible for individuals to have WS and *still* develop grammars that are indistinguishable from those of typically developing individuals. Thus the fact that we 'only' tested 12 individuals with WS in no way invalidates our central conclusions.

Another issue has to do with the group-by-condition interaction that we report between our WS and MA groups for the experimental and control conditions. The problem here, as pointed out to us, is that the interaction could very well be due to a ceiling effect (see graph 1). This may very well be the case, and this is something that we should acknowledge.

However, as was the case with the previous point, this observation does not affect our main conclusion that individuals with WS develop grammars that are governed by the same abstract principles also found in typically developing individuals. This is because what matters here for our primary question, as explained earlier, are the absolute levels of performance displayed by individuals with WS, and not how they behave compared to MA controls. Moreover, note that the fact that the group-by-condition interaction may indeed be an artifact, and thus that WS may be more like MA than we originally thought, would, if anything, strengthen our general position, rather than weaken it.

It was also pointed out to us that our MA control group has a mean non-verbal IQ outside the normal range (i.e., 118), and that to the extent that this is because our sample was recruited from a university environment, this may represent a confound with the different socioeconomic status of our WS group. Again, such differences are worth acknowledging, but it is hard to see how they would be problematic for our account. If elevated IQ, and presumably better working memory capacity, is what is responsible for better performance on the experimental conditions on the part of our MA group, then we would predict that a control group with a lower IQ mean would behave more like our WS group, thereby reinforcing our conclusion of 'normalcy'.

5.3. Modularity and the 'conservative hypothesis'

Having shown that our results are incompatible with the claims made by proponents of neuroconstructivism, we now turn to the other two approaches discussed earlier, namely modularity and the 'conservative hypothesis'. Beginning with the latter, our results fit well with the conclusion that individuals with WS do not acquire language differently than typically developing individuals. To be more precise, we have shown that individuals with WS, in spite of an altered genetic potential and mental retardation, nevertheless end up building grammatical systems which are governed by the *same* abstract principles that characterize typically developing and mature systems. However, we have also uncovered slight differences in behavioral levels on the experimental task between our WS and MA control groups. On the conservative hypothesis, such differences are what one may expect given the fact that individuals with WS are mentally retarded (Tager-Flusberg et al. 2003; Thomas and Karmiloff-Smith, 2003; Thomas, in press). In the next section, we come back this difference in behavioral levels between WS and MA, and we try to shed some light on its possible origins.

Whereas the compatibility of our empirical conclusions with the 'conservative hypothesis' is pretty straightforward, the implications of our results for modularity are a more delicate matter. For one thing, modularity has almost become taboo in discussions of language development in WS, and is often perceived as a relic of an outdated and simplistic view of WS that has now been abandoned by all but a handful of recalcitrant nativists. To be sure, Mervis and Becerra (2003) observe that most investigators studying language acquisition in WS reject modularity and that they no longer even mention it in their articles. This position, in turn, seems to follow from the often-repeated conclusion that while language abilities in WS may be impressive given these individuals' level of mental retardation, such abilities nevertheless never exceed what one might predict on the basis of mental age (Brock, 2007). Thus, language and general cognitive abilities do not dissociate, the argument continues, contra modularity.

However, as already discussed in detail in our criticism of neuroconstructivism (section 5.1.), we are skeptical of the conclusion that the fate of modularity boils down to whether behavioral levels on language tasks in WS exceed what one would predict on the basis of mental age. Thus, we would now like to discuss why we think that our results are at least *relevant* to the question of modularity. Since this topic remains highly controversial, we would like to underscore at the outset of the discussion the exploratory nature of the remarks to follow. To begin, we wish to emphasize the fact that we take our findings to be relevant to only *some*, but not *all*, aspects of modularity. Specifically, we believe that our results speak to the issue of domain-specificity[9] and robustness under deficit/ontogenetic invariance. In other words, our findings have no direct bearing on aspects of modularity such as speed, shallow outputs, obligatory firing, localization, etc. Conversely, whether such criteria turn out to be relevant or even true in the case of language has no bearing on the claims that we are making.

In regards to domain specificity, the principles under investigation here have, to the best of our knowledge, only been proposed in the context of linguistic explanations (see section 3 for detailed discussion). Thus, because the linguistic behavior of individuals with WS reported here can only be explained in terms of such principles[10], we take our results to have implications for domain-specificity. Turning to the issue of robustness under deficit - or what Fodor (1983) calls 'characteristic and specific breakdown patterns' - what our results highlight about WS is that mentally retarded individuals with a different genetic potential nonetheless manage to construct, in the course of development, a system of linguistic knowledge which is not only superficially impressive – as everybody would recognize – but,

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[9] In fact, it has been argued that domain specificity and *encapsulation* can be difficult to tease apart, and that doing so would depend on further assumptions regarding the nature of modules (see Barrett and Kurzban, 2006 for relevant discussion). Crucially, however, these considerations do not affect our line of argumentation or our main conclusions.

[10] Note that when we say 'can only be explained in terms of such principles', an important qualification is needed, namely 'for the time being'. As many other linguists have argued, including Chomsky and Hornstein and Lightfoot (1981), we are not claiming that the results reported here are in principle unexplainable in terms of domain general principles. Whether this can be done or not is an empirical question that future inquiry will have to answer. However, until it can be shown that the linguistic principles under investigation can be reduced to notions operating in other cognitive domains, it is fair to speak, if only from a methodological point of view, of domain-specificity.

crucially, one that is governed by the same abstract principles which characterize typically developing and mature systems.

Again, to situate our claims within the broader discussion on modularity in WS, our study is not intended as an empirical test of the computational system vs. lexicon distinction described above. Rather, we use the issue of domain-specificity to investigate the status of the computational system of language in individuals with WS. That being said, we do share with Clahsen and colleagues, as well as Pinker, the view that the computational system of language, qua *knowledge* of the relevant abstract principles, appears to be spared in WS. To add a final qualification, we do not intend for our results to adjudicate between one definition of modularity or another (e.g., Fodorian criteria, functional specialization, etc. See discussion above). At minimum, we are sympathetic to the modular view, broadly construed, because, by claiming that knowledge of grammar is spared/intact in WS (e.g., Clahsen and Almazan, 1998; Clahsen and Temple, 2003; Pinker, 1999), this approach correctly predicts the results that we report here regarding our main question.

5.4. Secondary question: WS vs. MA

We now turn to our secondary question, namely how the performance of individuals with WS compares to that of neurologically normal individuals. Recall that the relevant observation here is that while individuals with WS did not differ from MA on the control conditions (mean correct responses 90.87% vs. 94.53%, respectively, $p = 0.24$), they did in the experimental conditions (mean correct response 76.04% vs. 89.58%, $p < 0.05$). In principle, a possible explanation for this difference in performance between WS and MA could be that some of the *grammatical knowledge* required to perform well in the experimental conditions is compromised in WS. However, two key facts forcefully argue against such an interpretation. The first is that WS and MA performance is no different in the control conditions suggesting that people with WS, just like their MA matches, have appropriate knowledge of the meaning of all the elements interacting in the experimental conditions. The second is that in spite of the observed difference between the WS and MA matched groups, people with WS performed significantly above chance in the experimental conditions, thereby revealing knowledge of the syntactic principles under investigation. Thus, people with WS have all the relevant knowledge and yet do not perform as well as their MA matches in the experimental conditions. One plausible explanation is that the difference stems from limitations in the processing resources required to put that knowledge to use.

In fact, this latter conclusion would not be too surprising. To be sure, it comports well with a large body of work on typical language development as well as a growing body of work on WS. Let us first spell out the intuition and then discuss some of the related evidence. The idea here is that sentences like *The cat that didn't meow will get fish or milk* are not trivial to process – even for someone who has the relevant grammatical knowledge (for a similar conclusion regarding relative clauses, see Zukowski, 2001). More specifically, such sentences are more complex to process than sentences which only contain a subset of the elements involved (negation, *or*, relative clauses). Thus, whereas people with WS may encounter little to no difficulty processing a sentence which contains negation, disjunction, or a relativized subject, the level of processing difficulty gets compounded when all three pieces interact in the same sentence.

A similar phenomenon, also involving negation and scope, has recently been observed in the literature on typical language development. The relevant observation here is that typically developing preschoolers systematically differ from adults in the way they interpret ambiguous sentences containing negation and other quantified expressions (e.g, *every horse*, *two birds*) (e.g. *Every horse didn't jump over the fence, The Smurf didn't catch two birds*). Specifically, preschoolers appear to be restricted to the interpretation of such sentences that corresponds to the surface syntactic position of the quantificational elements involved (Musolino, Crain and Thornton, 2000; Musolino, 2006; Lidz and Musolino, 2002; Musolino and Gualmini, 2004)[11]. Yet, far from showing that preschoolers lack some of the knowledge that adults possess, such dramatic differences have in fact been shown to reflect differences in the processing resources deployed by the two groups during language comprehension (Musolino and Lidz, 2003; Musolino and Lidz, 2006; Gualmini, 2004. See also Trueswell et al, 1999 for related evidence).

Coming back to WS, the classic competence/performance distinction has also recently been shown to be of crucial importance. For example, Zukowski (2004) advises researchers to exercise caution when translating performance on a given test of language into conclusions about underlying linguistic abilities. Following this line of reasoning, Zukowski demonstrates how poor performance by individuals with WS on a task designed to assess comprehension of relative clauses led Karmiloff-Smith et al. (1997) to make the invalid inference that such performance must be due to deviant or impaired syntactic knowledge. In particular, Zulowski showed that, given felicitous conditions for producing object and subject-relative clauses, people with WS did just that. It is hard to imagine how sentences such as *The boy who is pointing to the cow turned purple* could be produced by an individual unless that individual possessed the grammatical knowledge to do so.

In sum, there are excellent reasons to believe that the difference between individuals with WS and MA matched children that was uncovered in our experimental conditions

[11] It should be pointed out that this tendency isn't absolute and that a number of factors have been uncovered which can lead children to behave in a more adult-like fashion (Musolino and Lidz, 2006; Gualmini, 2004, 2008; Viau, Lidz and Musolino, submitted). Moreover, this effect, typically seen in children, has also been induced in adults (Musolino and Lidz, 2003; Conroy, 2008).

involves processing – or 'performance' - differences rather than differences in underlying linguistic/ grammatical knowledge. In fact the correlation analyses we conducted are consistent with this picture. Recall that for both WS and MA matched participants, performance on the control conditions is significantly related to performance on the experimental conditions. Moreover, in both cases, performance on the 'negation' control is a significant predictor of overall performance in the experimental conditions, an observation which comports well with a large body of work in the literature on sentence processing (Horn, 1989 and references cited therein). Our hypothesis is that individuals with WS differ from MA matched individuals in the experimental conditions – but not in the control conditions - due to the compounded processing difficulty associated with the variables interacting in the experimental conditions (see Zukowski, 2001, for similar general conclusions). This hypothesis is consistent with the observation that individuals with mental retardation – including those with WS - show reduced verbal working memory capacities as compared to mental age matches (Clarke and Clarke, 1974; Ellis, 1978; Hulme and Mackenzie, 1992; McDade and Adler, 1980; Vicari, Carlesimo, Albertini and Caltagirone, 1994; Vicari, Carlesimo, and Caltagirone, 1995; Vicari, Carlesimo, Brizzolara and Pezzini, 1995). Finally, this interpretation is corroborated by the fact that individuals with less efficient processing skills, i.e., typically developing 4-year-olds, like WS individuals, but unlike MA controls, experience more difficulty with the experimental conditions compared to the control conditions.

6. Concluding remarks

According to much current work on language development in WS (see Mervis and Becerra, 2003; and Brock, 2007 for extensive reviews), earlier reports of striking grammatical abilities in this disordered population (i.e., Bellugi et al., 1988) led to 'exaggerated' claims on the part of some theorists who enthusiastically described WS as a textbook example illustrating the modularity of language (Jackendoff, 1994; Pinker, 1994; Anderson, 1998; Piatelli-Palmarini, 2001). No less striking was the sharp reaction that followed subsequent work on this topic and led to theoretical views and empirical claims, couched in a new framework called neuroconstructivism, that flatly contradicted earlier accounts of 'spared' grammar and modularity (e.g., Karmiloff-Smith, 1998). Those claims about the superficial and deviant nature of WS language, it now turns out, are also unrealistic (Brock, 2007; Thomas, in press), although detailed discussions of why this is the case – surely as important as detailed discussions of why modularity fails – have not been forthcoming.

In this article, we presented new empirical evidence showing that knowledge of core, abstract principles of grammar is present and engaged in WS, just as it is in typically developing and mature individuals. This conclusion, in turn, suggests that language acquisition does not appear to be fundamentally altered in WS, an observation that comports well with the emerging consensus that language development in WS is best accounted for by the 'conservative hypothesis' (Brock, 2007; Thomas, in press; Tager-Flusberg et al., 2003). If so, one cannot help but wonder how different the conservative hypothesis really is from some versions of the modularity thesis. After all, saying that individuals with WS do not seem to acquire language any differently than typically developing individuals amounts to acknowledging the resilience of language in the face of genetic abnormalities and mental retardation, as well as the specific and abstract nature of the mental representations involved in WS language – two hallmarks of modular systems according to the classic Fodorian view.

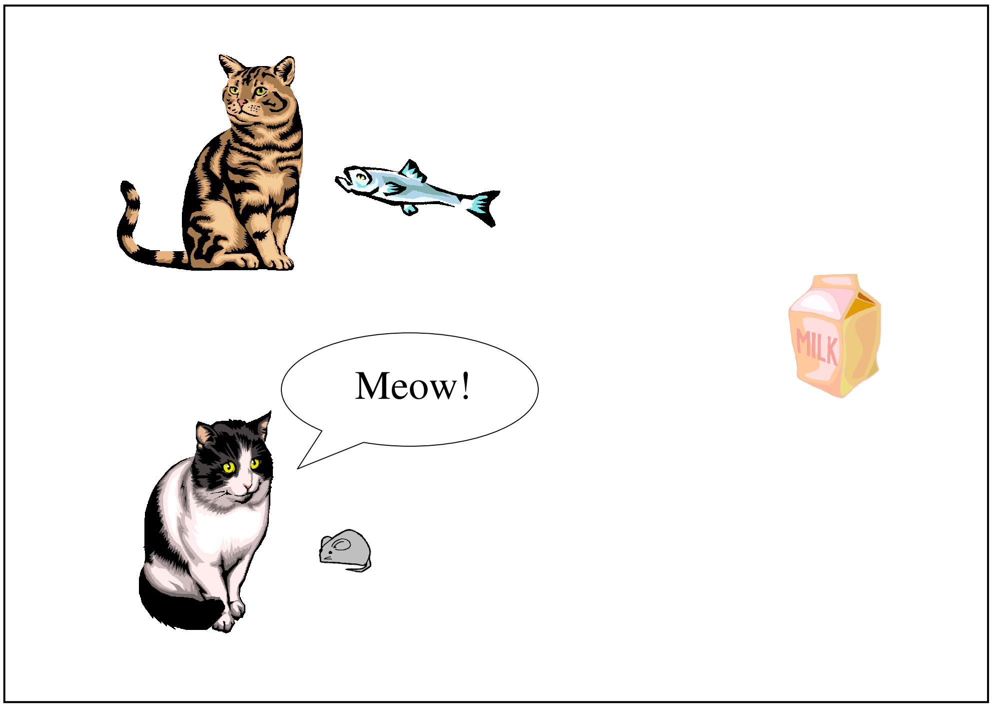
Appendix 1: experimental conditions[12]

Vignette	C-command statements	Outcome	True/False
Two tow-trucks, a motorcycle, a car, and a boat.	The tow-truck that beeps its horn will not pick up a car or a motorcycle.	The relevant tow-truck picked up the boat.	True
Two cats, a fish, milk, and a mouse.	The cat who meows will not be given a fish or milk.	The relevant cat gets the mouse.	True
Two policemen, a cup of coffee, doughnuts, and a newspaper.	The policeman who is blowing his whistle will not be given a newspaper or doughnuts.	The relevant policeman gets the cup of coffee.	True
Two girls, a racket, a towel, and water.	The girl who is playing tennis will not be given a towel or water.	The relevant girl gets the racket.	True
Two ducks, a fish, bread, and grapes.	The duck who quacks will not be given the fish or the bread.	The relevant duck gets the fish.	False
Two clowns, a jewel, a coin, and some dollar bills.	The clown who is holding a flower will not be given a jewel or a coin.	The relevant clown gets the coin.	False
Two boys, pop corn, a candy-bar, and soda.	The boy with the money will not be given the candy-bar or the popcorn.	The relevant boy gets the popcorn.	False
Two kids, a ball, suntan lotion, and an umbrella.	The kid who is building a castle will not be given a ball or an umbrella.	The relevant kid gets the umbrella.	False
Vignette	**Precede statements**	**Outcome**	**True/False**
Two owls, bugs, a bird, and a mouse.	The owl that does not hoot will get bugs or a mouse.	The relevant owl gets the mouse.	True
Two monkeys, a football, bananas, and an apple.	The monkey who is not asleep will get bananas or a ball.	The relevant monkey got the bananas.	True
Two snowmen, skates, a sled, and skis.	The snowman who does not wave will get skates or a sled.	The relevant snowman got the sled.	True

[12] As one of the reviewers pointed out, all but one of the 'c-command' statements contains a passive whereas none of the precede statements do. This is an accidental feature of the design which, as the same reviewer also pointed out, did not seem to have affected the results. In fact, it is not immediately clear how this difference could have affected the results, except perhaps that the presence of passives might have made the 'c-command' statements more difficult to process. However, results from the c-command condition indicate that this didn't seem to have been the case.

Two boys, candy, ice-cream, and a coin.	The boy who is not running will get candy or ice-cream.	The relevant boy gets the candy.	True
Two cowboys, boots, a saddle, and a hat.	The cowboy who is not riding will get boots or a hat.	The relevant cowboy gets the saddle.	False
Two pirates, a map, gold, and a jewel.	The pirate who is not sitting will get gold or a map.	The relevant pirate gets the jewel.	False
Two dogs, bones, French fries, and a steak.	The dog who does not bark will get bones or French fries.	The relevant dog got the steak.	False
Two bees, honey, flowers, and a hive.	The bee that does not buzz will get flowers or honey.	The relevant bee got the hive.	False

Sample context



The cat who meows will not be given a fish or milk

Step 1: the two cats appear
Step 2: presentation of the pre-recorder target sentence: "The cat who meows will not be given a fish or milk"

Step 3: pre-recorded voice: “Here’s a fish”, followed by the appearance of the fish. Pre-recorded voice: “Here’s some milk”, followed by the appearance of the milk. Pre-recorded voice: “And here’s a mouse”, followed by the appearance of the mouse.
Step 4: repeat of the target sentence
Step 5: Black and white cat meows (sound effect + text bubble)
Step 6: As mouse moves to cat who meowed, pre-recorded voice: “You get a mouse” and as fish moves to the other cat, pre-recorded voice: “And you get a fish”
Step 7: Repeat of the target sentence

Appendix 2: control conditions[13]

Negation Statements	**True/False**
The boy did not get a bicycle.	True
The butterfly did not land on the flowers.	True
The tired monkey did not get a banana.	True
The jeans did not get washed.	True
The green frog could not jump on the rock.	False
The little girl is not making cookies.	False
The penguin did not catch the fish.	False
The little girl will not get the watering can.	False
Disjunction statements	
The policeman will get a cup of coffee or the doughnuts.	True
The boy will get a banana or French fries.	True
The toolbox will get a hammer or a screw-driver.	True
This dinner comes with water or a soda	True
The girl will get a cat or a dog.	False
The hippo will get soap or shampoo.	False
The boy will get the beach ball or the sun tan lotion.	False
The tickets are for the airplane or the movie theatre.	False
Relative Statements	
The man who has a red tie is walking a dog.	True
The car that beeps its horn will get the new tires.	True
The fireman who has a hose has the dog.	True
The apple that is on top of the book has a worm in it.	True
The rabbit who has on blue pants is playing guitar.	False
The clown who is on a bike is holding a yellow flower.	False
The little girl who has blond hair has two dolls.	False
The rooster who is on the fence will crow.	False
DeMorgan Statements	

[13] As was pointed out by one of the reviewers, the statements in the various control conditions differ with regards to tense, as well as animacy of the subjects. These were accidental features of the design, and judging from the very high proportions of correct responses from all participants on these conditions, those differences did not seem to have played a significant role in the pattern of results obtained.

The baseball player will not get the glove or the hat.	True
The bunny will not get lettuce or tomatoes.	True
The bee did not land on the white or the yellow flower.	True
The bear will not get ketchup or broccoli.	True
The man will not get the brush or the razor.	False
The kid will not get playing cards or a yoyo.	False
The elephant will not get peanuts or cheese.	False
The shopping cart will bet get oranges or watermelon.	False

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